Designation: F 1704 – 99

An American National Standard

# Standard Test Methods for Performance of Commercial Kitchen Ventilation Systems[1]

This standard is issued under the fixed designation F 1704; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 These test methods cover the performance evaluation of exhaust hoods with commercial cooking appliances and associated replacement air configurations. The scope of these test methods include:

1.1.1 Characterization of capture and containment performance of hood, appliance(s), and replacement air system during cooking and non-cooking conditions;

1.1.2 Determination of appliance heat gain to space derived from the measurement and calculation of appliance energy consumption, energy exhausted, and energy to food, based on a system energy balance;

1.1.3 Parametric evaluation of operational or design variations in appliances, hoods, or supply air.

1.2 These test methods are contained in the sections indicated as follows:

| | Sections |
|---|---|
| Test Method to Determine Threshold of Capture and Containment | 8 |
| Test Method to Determine Heat Gain to Space | 16 |

1.3 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:*

F 1275 Test Method for the Performance of Griddles[2]

F 1361 Test Method for the Performance of Open Deep Fat Fryers[2]

F 1484 Test Method for the Performance of Steam Cookers[2]

F 1496 Test Method for the Performance of Convection Ovens[2]

F 1521 Test Method for the Performance of Range Tops[2]

F 1605 Test Method for Performance of Double-Sided Griddles[2]

F 1639 Test Method for Performance of Combination Ovens[2]

F 1695 Test Method for Performance of Underfired Broilers[2]

F 1785 Test Method for Performance of Steam Kettles[2]

F 1787 Test Method for Performance of Rotisserie[2]

F 1817 Test Method for the Performance of Conveyor Ovens[2]

2.2 *NFPA Standard:*[3]

NFPA 96 Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations

2.3 *ASHRAE Standards:*[4]

"A Field Test Method for Determining Exhaust Rates in Grease Hoods for Commercial Kitchens," *ASHRAE Transactions*, Vol 100, Part 2, 1994

ASHRAE Guideline 2-1986 (RA90) Engineering Analysis of Experimental Data

2.4 *ANSI Standards:*[5]

ANSI/ASHRAE 51 and ANSI/AMCA 210 Laboratory Method of Testing Fans for Rating

2.5 *ICC Standards:*[6]

International Mechanical Code

NOTE 1—The replacement air and exhaust system terms and their definitions are consistent with terminology used by the American Society of Heating, Refrigeration, and Air Conditioning Engineers, see Ref (**1**).[7] Where there are references to cooking appliances, an attempt has been made to be consistent with terminology used in the test methods for commercial cooking appliances. For each energy rate defined as follows, there is a corresponding energy consumption that is equal to the average energy rate multiplied by elapsed time. Electric energy and rates are expressed in W, kW, and kWh. Gas Energy consumption quantities and

[1] These test methods are under the jurisdiction of ASTM Committee F-26 on Food Service Equipment and are the direct responsibility of Subcommittee F26.06 on Productivity and Energy Protocol.

Current edition approved Oct. 10, 1999. Published January 2000. Originally published as F 1704 – 96. Last previous edition F 1704 – 96.

[2] *Annual Book of ASTM Standards*, Vol 15.07.

[3] Available from National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269–9101.

[4] Available from American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc., 1791 Tullie Circle, NE, Atlanta, GA 30329.

[5] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[6] Available from International Code Council, 5203 Leesburg Pike, Suite 708, Falls Church, VA 22041.

[7] The boldface numbers in parentheses refer to the list of references at the end of these test methods.

rates are expressed in Btu, kBtu, and kBtu/h. Energy rates for natural gas-fueled appliances are based on the higher heating value of natural gas.

## 3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *energy rate*, *n*—the average rate at which an appliance consumes energy during a specified condition (for example, idle or cooking).

3.1.2 *appliance/hood energy balance*, *n*—mathematical expression of appliance, exhaust system, and food energy relationship.

[actual appliance energy consumption]
= [heat gain to space from appliance(s)] + [energy exhausted] + [energy-to-food, if any]

3.1.3 *cold start*, *n*—the condition in which appliances are energized with all components being at nominal room temperature.

3.1.4 *cooking energy consumption rate*, *n*—the average rate of energy consumed by the appliance(s) during heavy-load cooking specified in appliance test methods in 2.1.

3.1.4.1 *Discussion*—In this test method, this rate is measured for heavy-load cooking in accordance with the applicable test method.

3.1.5 *exhaust energy rate*, *n*—the average rate at which energy is removed from the test system.

3.1.6 *exhaust flow rate*, *n*—the volumetric flow of air (plus other gases and particulates) through the exhaust hood, measured in standard cubic feet per minute, scfm (standard litre per second, sL/s). This also shall be expressed as scfm per linear foot (sL/s per linear metre) of active exhaust hood length.

3.1.7 *energy-to-food rate*, *n*—the average rate at which energy is transferred from the appliance to the food being cooked, using the cooking conditions specified in the applicable test methods.

3.1.8 *fan and control energy rate*, *n*—the average rate of energy consumed by fans, controls, or other accessories associated with cooking appliance(s). This energy rate is measured during preheat, idle, and cooking tests.

3.1.9 *heat gain energy rate from appliance(s)*, *n*—the average rate at which energy is transferred from appliance(s) to the test space around the appliance(s), exclusive of the energy exhausted from the hood and the energy consumed by the food if any.

3.1.9.1 *Discussion*—This gain includes conductive, convective, and radiant components. In conditions of complete capture, the predominant mechanism of heat gain consists of radiation from the appliance(s), and radiation from hood. In the condition of hood spillage, heat is gained additionally by convection.

3.1.10 *hood capture and containment*, *n*—the ability of the hood to capture and contain grease-laden cooking vapors, convective heat, and other products of cooking processes. Hood capture refers to the products getting into the hood reservoir from the area under the hood while containment refers to the products staying in the hood reservoir.

3.1.11 *idle energy consumption rate*, *n*—the average rate at which an appliance consumes energy while it is idling, holding, or ready-to-cook, at a temperature specified in the applicable test method from 2.1.

3.1.12 *latent heat gain*, *n*—the energy added to the test system by the vaporization of liquids that remain in the vapor phase prior to being exhausted, for example, by vapor emitted by products of combustion and cooking processes.

3.1.13 *makeup air handling hardware*:

3.1.13.1 *diffuser, n*—an outlet discharging supply air in various directions and planes.

3.1.13.2 *grille, n*—a covering for any opening through which air passes.

3.1.13.3 *register, n*—a grille equipped with a damper.

3.1.13.4 *throw, n*—the horizontal or vertical axial distance an air stream travels after leaving an air outlet before maximum stream velocity is reduced to a specified terminal velocity, for example, 100, 150, or 200 ft/min (0.51, 0.76, or 1.02 m/s).

3.1.14 *measured energy input rate*, *n*—the maximum or peak rate at which an appliance consumes energy measured during appliance preheat, that is, measured during the period of operation when all gas burners or electric heating elements are set to the highest setting.

3.1.15 *radiant heat gain*, *n*—the fraction of the space energy gain provided by radiation.

3.1.15.1 *Discussion*—Radiant heat gain is not immediately converted into cooling load. Radiant energy must first be absorbed by surfaces that enclose the space and objects in the space. As soon as these surfaces and objects become warmer than the space air, some of their heat is transferred to the air in the space by convection. The composite heat storage capacity of these surfaces and objects determines the rate at which their respective surface temperatures increase for a given radiant input and thus governs the relationship between the radiant portion of heat gain and its corresponding part of the cooling load. The thermal storage effect is critically important in differentiating between instantaneous heat gain for a given space and its cooling load for that moment.



3.1.16 *rated energy input rate*, *n*—the maximum or peak rate at which an appliance consumes energy as rated by the manufacturer and specified on the appliance nameplate.

3.1.17 *replacement air*, *n*—air deliberately supplied into the space (test room), and to the exhaust hood to compensate for the air, vapor, and contaminants being expelled (typically referred to as makeup air).

3.1.18 *supply flow rate*, *n*—the volumetric flow of air supplied to the exhaust hood in an airtight room, measured in standard cubic feet per minute, scfm (standard litre per second, sL/s). This also shall be expressed as scfm per linear foot (sL/s per linear metre) of active exhaust hood length.

3.1.19 *threshold of capture and containment*, *n*—the conditions of hood operation in which minimum flow rates are just sufficient to capture and contain the products generated by the appliance(s). In this context, two minimum capture and containment points are determined, one for appliance idle condition, and the other for heavy-load cooking condition.

3.1.20 *uncertainty*, *n*—a measure of the precision errors in specified instrumentation or the measure of the repeatability of a reported result.

3.1.21 *ventilation*, *n*—that portion of supply air that is outdoor air plus any recirculated air that has been treated for the purpose of maintaining acceptable indoor air quality.

## 4. Significance and Use

4.1 *Threshold of Capture and Containment*—This test method describes flow visualization techniques that are used to determine the threshold of capture and containment (c&c) for idle and specified heavy cooking conditions. The threshold of c&c can be used to estimate minimum flow rates for hood/appliance systems.

4.2 *Heat Gain to Space*—This test method determines the heat gain to the space from a hood/appliance system.

NOTE 2—To maintain a constant temperature in the conditioned space, this heat gain must be matched by space cooling. The space sensible cooling load, in tons, then equals the heat gain in Btu/h divided by the conversion factor of 12 000 Btu/h (3.412 W) per ton of cooling. Appliance heat gain data can be used for sizing air conditioning systems. Details of load calculation procedures can be found in ASHRAE, see Ref **(2)** and Ref **(3)**. The calculation of associated cooling loads from heat gains to the test space at various flow rates can be used along with other information by heating, ventilation, air conditioning (HVAC), and exhaust system designers to achieve energy-conservative, integrated kitchen ventilation system designs.

4.3 *Parametric Studies*—This test method also can be used to conduct parametric studies of alternative configurations of hoods, appliances, and replacement air systems. In general, these studies are conducted by holding constant all configuration and operational variables except the variable of interest. This test method, therefore, can be used to evaluate the following:

4.3.1 The overall system performance with various appliances, while holding the hood and replacement air system characteristics constant.

4.3.2 Entire hoods or characteristics of a single hood, such as end panels, can be varied with appliances and replacement air constant.

4.3.3 Replacement air characteristics, such as makeup air location, direction, and volume, can be varied with constant appliance and hood variables.

## 5. Apparatus

5.1 Specialized apparatus requirements are listed in the Apparatus Section in each method.

5.2 The general configuration and apparatus necessary to perform this test method is shown schematically in Fig. 1 and described in detail in Ref **(4)**. Example test facilities are described in Refs **(5,6,7)**. The exhaust hood under test is connected to an exhaust duct and fan and mounted in an airtight room. The exhaust fan is controlled by a variable speed drive to provide operation over a wide range of flow rates. A complementary makeup air fan is controlled to balance the exhaust rate, thereby maintaining a negligible static pressure difference between the inside and outside of the test room. The test facility includes the following:

5.2.1 *Airtight Room*, with sealable access door(s), to contain the exhaust hood to be tested, with specified cooking appliance(s) to be placed under the hood. The minimum volume of the room shall be 6000 $ft^3$. The room air leakage shall not exceed 20 scfm (9.4 sL/s) at 0.2 in. w.c. (49.8 Pa).

5.2.2 *Exhaust and Replacement Air Fans*, with variable-speed drives, to allow for operation over a wide range of exhaust air flow rates.

5.2.3 *Control System and Sensors*, to provide for automatic or manual adjustment of replacement air flow rate, relative to exhaust flow rate, to yield a differential static pressure between inside and outside of the airtight room not to exceed 0.05 in. w.c. (12.5 Pa).

5.2.4 *Air Flow Measurement System Laminar Flow Element*, AMCA 210 or equivalent nozzle chamber, mounted in the replacement or exhaust airstream, to measure air flow rate.

NOTE 3—Because of potential problems with measurement in the hot, possibly grease-laden exhaust air stream, exhaust air flow rate can be determined by measuring the replacement air flow rate on the supply side. This requires the design of an airtight test facility that ensures the supply rate equals the exhaust rate since air leakage outside the system boundary, that is, all components between supply and exhaust blowers making up the system, is negligible.



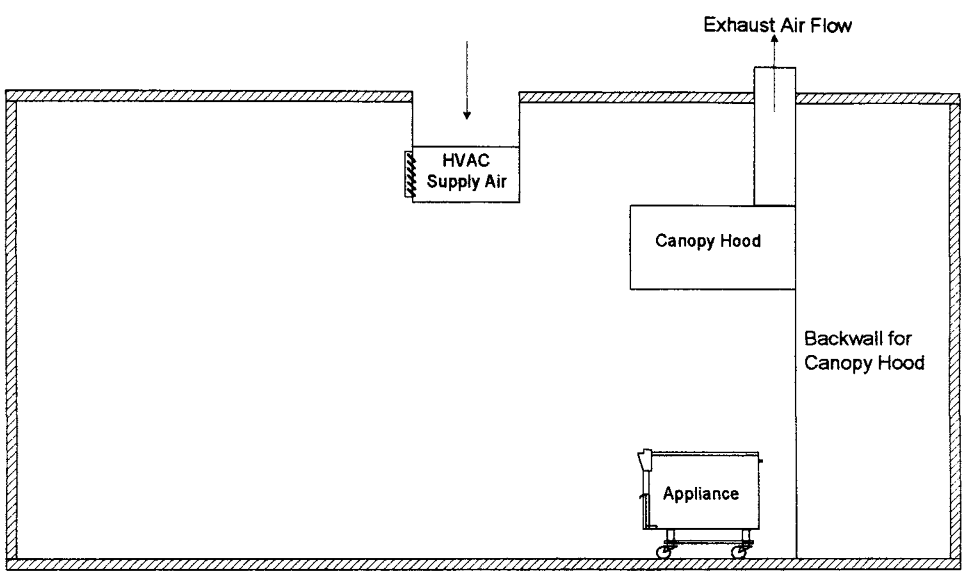


**FIG. 1 Test Space Cross Section**

NOTE 4—Laminar flow elements have been used as an equivalent alternative to the flow nozzles in AMCA 210 (see 2.4).

5.2.5 *Data Acquisition System*, to provide for automatic logging of test parameters.

## 6. Reagents and Materials

6.1 *Water and Test Food Products*—Use water and test food products to determine energy-to-food as specified in the standards listed in Section 2.

## 7. Sampling

7.1 *Hood and Appliance(s)*—Select representative production models for performance testing.

## TEST METHOD TO DETERMINE THE THRESHOLD OF CAPTURE AND CONTAINMENT

## 8. Scope

8.1 This test method characterizes the capture and containment performance of commercial kitchen ventilation systems.

## 9. Summary of Test Method

9.1 This test method uses flow visualization to determine the threshold of c&c of a hood/appliance combination under idle and cooking conditions.

## 10. Apparatus

10.1 *Flow Enhancement Visualization Systems*:

10.1.1 *Optical Systems*, such as schlieren visualization, see Fig. 2.

10.1.2 *Seeding Methods*, such as theater fog, smoke (for example, puffers, wands, candles, and so forth), neutrally buoyant bubbles, or other equivalent means.

NOTE 5—The seeding process shall only introduce small amounts of tracer material to avoid disturbances to the air flow. A seeding process introduces a tracer which artificially seeds the thermal plume that is rising between the cooking surface and the perimeter of the hood for visualization, and thereby making it more visible. This flow path will be generated continuously throughout the determination of the threshold capture and containment flow rate by suitable equipment and introduced at a trace rate only and not at an appreciable volume.

10.1.3 *Illumination*, such as with high-intensity, focused lighting.

NOTE 6—A 300-W halogen lamp with a lens and a dark backdrop in place aids in visualizing seeded effluent.

## 11. Preparation of Apparatus

11.1 Install the test hood in the airtight room in accordance with the applicable ASTM test method, see 2.1, and as close to the manufacturer's instructions, or as determined by particular experimental conditions.

11.2 Makeup air shall be supplied to diffusers as determined by the test conditions. The specific arrangement shall be noted in the report.

NOTE 7—In general, makeup air provided to the test space shall be admitted from diffusers located as far away from the hood as possible. The principal direction of makeup air flow from these diffusers shall be away from the exhaust hood in order to minimize the effects the air flow might have on the capture and containment process. Additionally, it is important to adjust registers to provide a horizontally symmetric throw of supply air from diffusers. The general arrangement of diffusers and supply air is shown in Fig. 3. Document supply air configuration and damper positions,



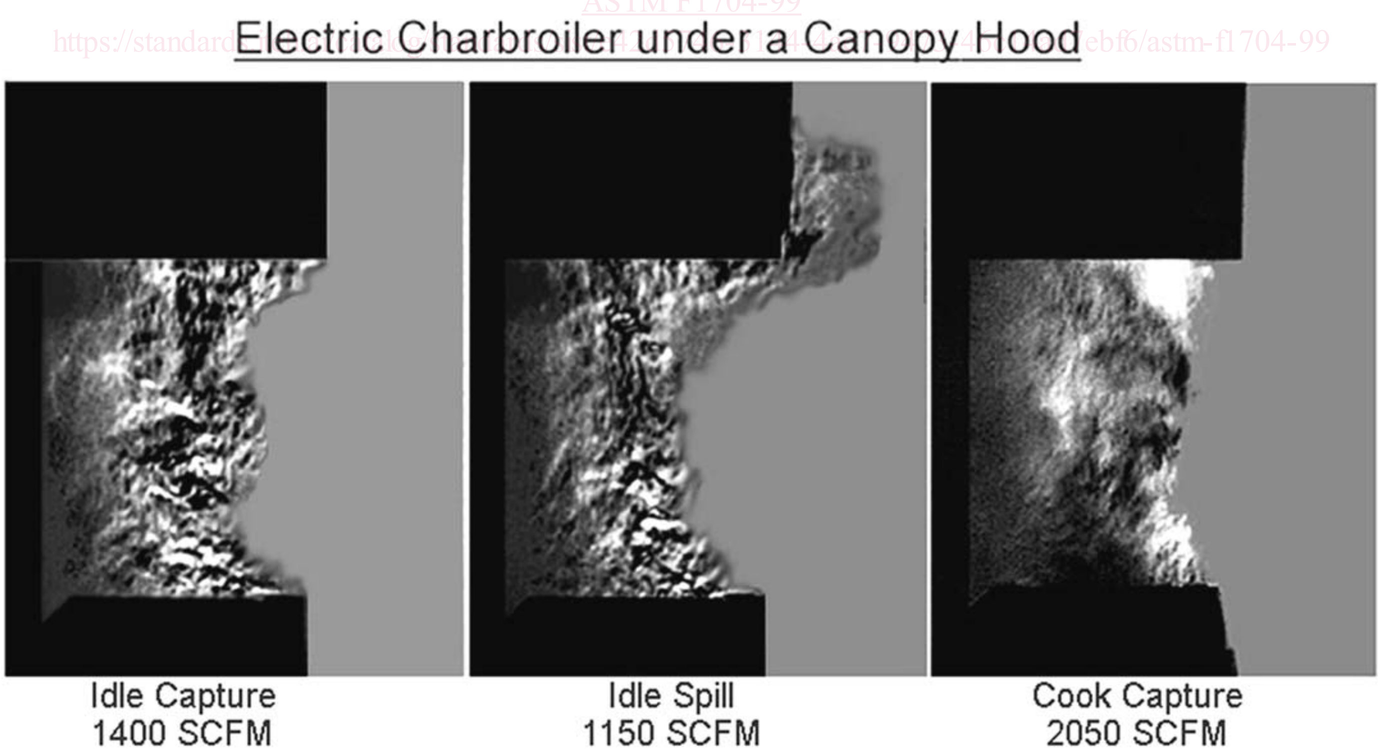


FIG. 2 Example of Schlieren Flow Visualization

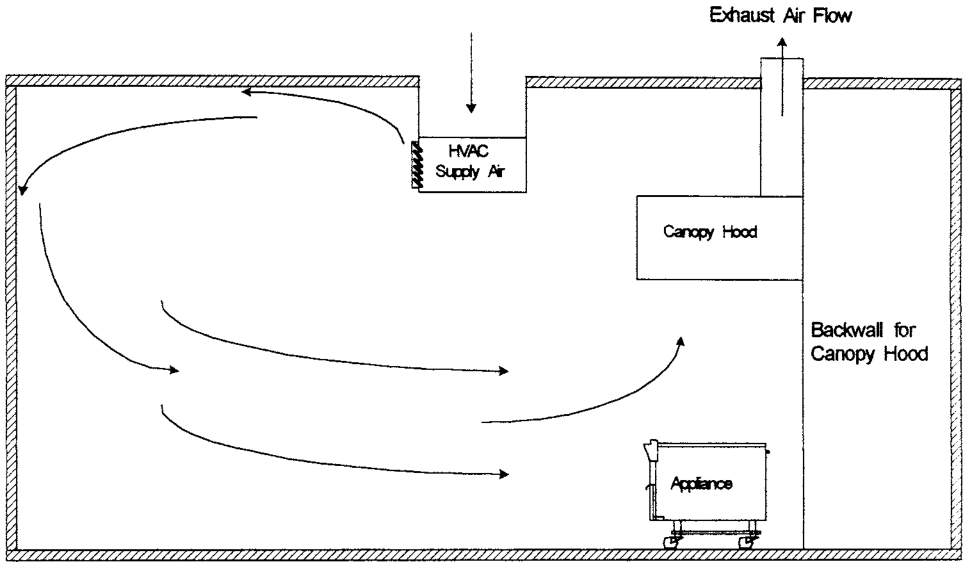


**FIG. 3 Supply Air Configuration**

following the manufacturer's recommendations.

11.3 Connect the appliance(s) to energy sources and test the instruments in accordance with the applicable test methods. Included is the connection to calibrated energy test meters and for gas equipment and the connection to a pressure regulator downstream of the test meter. Electric and gas energy sources are adjusted to within 2.5 % of voltages and pressures, respectively, as specified by the manufacturer's instructions or in accordance with applicable test methods.

11.4 Once the equipment has been installed, draw a front and side view of the test setup.

## 12. Calibration

12.1 Calibrate the instrumentation and data acquisition system in accordance with device requirements to ensure accuracy of measurements.

12.2 Calibrate the flow measurement systems in accordance with the manufacturer's specifications and installed in accordance with AMCA 210. Other flow measurement systems must meet or exceed AMCA 210 accuracy requirements.

12.3 Calibrate humidity measuring instruments in accordance with the manufacturer's specifications annually against NIST-traceable reference meters. Relative humidity accuracy within ±0.5 % at 40 % RH and ±1.25 % at 95 % RH.

12.4 Calibrate all temperature sensors in the temperature Measurements Systems upon receipt to within +2°F against a NIST-traceable temperature reference over the range of expected measurements.

## 13. Procedure

NOTE 8—The following procedures are the instructions for implementing the test method for determining the threshold capture and containment flow rate for appliance(s) during idle and cooking conditions under island, wall-mounted canopy, and backshelf hoods. The procedure will establish two threshold capture and containment flow rates, one for appliance idling and the other for heavy-load cooking, $cfm_{idle}$ and $cfm_{cook}$, respectively.

13.1 Conduct the capture and containment test for idle and cooking conditions a minimum of three times. Additional test runs may be necessary to obtain the required precision of the reported test results (Annex A1).

13.2 Set the initial flow rate high enough to be certain to capture and contain the thermal plume and contaminants produced from the cooking appliance(s) under either idle or cooking conditions. If uncertain where this flow rate is, set the exhaust flow rate initially at the code specified rate (see 2.5) and set the makeup at approximately the same flow rate. Keep room differential pressure within 0.05 in. w.c. by opening the laboratory door or by using automatic pressure equilibration. Turn off all test space recirculating systems.

13.3 Establish the idle or cooking threshold capture and containment flow rate, whereby the appliance is operating to maintain a ready to cook condition (for the idle test) or a full-load cooking condition (for the cook test) using a flow enhancement visualization system. While idling, the appliances shall cycle for at least 2 periods; while cooking, the appliance must cycle a minimum of one full-load cook cycle. The hood must show capture and containment during the full cycle period over the full hood perimeter during both idle and cooking conditions when using a flow enhancement visualization system.

13.4 During the test, reduce the exhaust flow rate until the hood begins to spill. Any observed leak moving beyond 3 in. (7.6 cm) from the hood face will be construed to have escaped from the hood, even if it may appear to be drawn back into the hood.

13.5 Gradually increase the exhaust flow rate in fine increments until full capture and containment is achieved.

13.6 Note the exhaust fan RPM ($N_{exh}$) and supply fan RPM ($N_{supply}$).

13.7 Perform Runs 2 and 3 by repeating 13.2-13.6 to ensure proper capture and containment of the entire thermal plume at this flow rate.

13.8 Allow hood/appliance system to stabilize 5 min at the maximum exhaust rpm required for capture and containment, noted in 13.6. After the stabilization period, take a 1-min average of the actual flow. Note whether it is a measurement of the air exhausted or the makeup air supplied to an airtight room.

NOTE 9—The makeup air supplied is representative of the flow requirements necessary for roof top units supplying a restaurant during typical appliance idling at the capture and containment rate.

13.9 Calculate the corresponding air flow rate at standard conditions, in accordance with AMCA 210.

## 14. Calculation and Report

14.1 *Capture and Containment Flow Rate Percent Uncertainty*:

14.1.1 Calculate mean of capture and containment flow rates in accordance with Annex A1.

14.1.2 Calculate standard sample deviation of capture and containment flow rates in accordance with Annex A1.

14.1.3 Calculate percent uncertainty of capture and containment flow rates expressed as a percentage.

14.2 *Test Hood and Appliance(s)*—Summarize the physical and operating characteristics of the exhaust hood and installed appliances, reporting all manufacturers' specifications and deviations therefrom. Include in the summary hood and appliance(s) nameplates specifications; hood overhangs; and hood and appliance(s) height(s) and size. Describe the specific appliance operating condition (for example, type and amount of product cooked, number of burners or elements on, and actual control settings).

14.3 *Apparatus*—Describe the physical characteristics of the airtight room, exhaust and makeup air systems, and installed instrumentation.

14.4 *Data Acquisition*:

14.4.1 The following parameters are determined or known prior to each test run:

14.4.1.1 *HV*, Btu/ft$^3$—Higher (gross) saturated heating value of natural gas.

14.4.1.2 $C_{pa}$, specific heat of dry air, 0.24 Btu/[$lb_a$·°F].

14.4.1.3 $C_{pv}$, specific heat of water vapor, 0.44 Btu/[$lb_a$·°F].

14.4.1.4 $R_a$, gas constant for dry air, 53.352 ft·$lb_f$ / [$lb_m$·°F].

14.4.2 The following parameters are monitored and recorded during each test run or at the end of each test run, or both:

14.4.2.1 $cfm_{idle}$, standard cubic feet per minute, scfm-Threshold capture and containment exhaust flow rate under idle condition.

14.4.2.2 $cfm_{cook}$, standard cubic feet per minute, scfm-Threshold capture and containment exhaust flow rate under heavy-load cooking mode.

14.4.2.3 $N_{exh}$, exhaust fan RPM at threshold of capture and containment.

14.4.2.4 $N_{supply}$, supply fan RPM at threshold of capture and containment.

14.4.2.5 $V_{gas}$, cubic feet, ft$^3$—Volume of gas consumed by the appliance(s) over the test period.

14.4.2.6 $cfm_{gas}$, cubic feet per minute, cfm—Average flow rate of combustion gas consumed over the test period.

14.4.2.7 $E_{ctrl}$, Btu/h—Average rate of energy consumed by controls, indicator lamps, fans, or other accessories associated with cooking appliance(s).

14.4.2.8 $E_{app}$, Btu/h—Average rate of energy consumed by burners of gas appliances, or heating elements of electric appliances, to maintain set operating temperature.

14.4.2.9 $E_{input}$, Btu/h—Average rate of total energy (that is, $E_{app} + E_{ctrl}$) consumed by the appliance(s).

14.4.2.10 $E_{peak}$, Btu/h—Average rate of actual appliance(s) energy input, measured during the first 10 min of the preheat period.

14.4.2.11 $\Delta P_{neut}$, in. $H_2O$—Static pressure differential between inside and outside the test space, measured at the neutral zone of the test space.

14.4.2.12 $P_{gas}$, in. Hg—Gas line gage pressure.

14.4.2.13 *Bp*, in. Hg—Ambient barometric pressure.

14.4.2.14 $T_{is}$, °F—Average dry bulb temperature of supply air into the test space.

14.4.2.15 $T_{exh}$, °F—Average dry bulb temperature of exhaust air.

14.4.2.16 $T_{tree}$, °F—Average dry bulb temperature of makeup air supplied from the test space

14.4.2.17 $T_{space}$, °F—Average dry bulb temperature of test space.

14.4.2.18 $T_{gas}$, °F—Average dry bulb temperature of the gas consumed by the appliance(s).

14.4.2.19 $T_{w,tree}$, °F—Average wet bulb temperature of test space air, measured at the aspirated thermocouple tree(s) plane.

14.4.2.20 $T_{test}$, minutes—Elapsed time of the test run.

14.4.3 The following parameters are calculated at the end of each test run:

14.4.3.1 $C_p$, Btu/lb°F—Specific heat of supply [makeup] air.

14.4.3.2 $P_{cf}$, dimensionless—Pressure correction factor.

14.4.3.3 $T_{cf}$, dimensionless—Temperature correction factor.

14.4.3.4 $scfm_{tree}$, scfm—Flow rate of makeup air supplied from the test space at standard density air.

14.4.3.5 $M_{sup}$, lb/h—Total mass flow rate of air supplied by the system.

14.4.3.6 $W_{sup}$, $lb_v/lb_a$—Equivalent humidity ratio of makeup air supplied from the hood and test space.

14.4.3.7 $W^*_{s,tree}$, $lb_v/lb_a$—Humidity ratio at saturation of makeup air supplied from the test space.

14.4.3.8 $W_{tree}$, $lb_v/lb_a$—Humidity ratio of makeup air supplied from the test space.

14.4.3.9 $RH_{tree}$, %—Relative humidity of air supplied from the test space.

14.4.3.10 $\nu_{tree}$, (ft$^3$/$lb_a$)—Specific volume of makeup air supplied from the test space.

14.5 Report the threshold capture and containment flow rate for a particular hood/appliance(s) system based on flow visualization techniques. The standard flow rate will be reported along with its associated uncertainty.

14.5.1 Note the type of measurement system. Using the flow rates acquired in 13.9 convert the flow rates to standard conditions in accordance with AMCA 210. Note whether it is a measurement of the air exhausted or the makeup air supplied to an airtight room.

## 15. Precision and Bias

15.1 *Precision*: